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Original communication

# Dental age assessment of young Iranian adults using third molars: A multivariate regression study

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ABSTRACT

*Background:* In recent years, a noticeable increase in forensic age estimations of living individuals has been observed. Radiologic assessment of the mineralisation stage of third molars is of particular importance, with regard to the relevant age group. To attain a referral database and regression equations for dental age estimation of unaccompanied minors in an Iranian population was the goal of this study. Moreover, determination was made concerning the probability of an individual being over the age of 18 in case of full third molar(s) development.

*Materials and methods:* Using the scoring system of Gleiser and Hunt, modified by Köhler, an investigation of a cross-sectional sample of 1274 orthopantomograms of 885 females and 389 males aged between 15 and 22 years was carried out. Using kappa statistics, intra-observer reliability was tested. With Spearman correlation coefficient, correlation between the scores of all four wisdom teeth, was evaluated. We also carried out the Wilcoxon signed-rank test on asymmetry and calculated the regression formulae.

*Results:* A strong intra-observer agreement was displayed by the kappa value. No significant difference ($p$-value for upper and lower jaws were 0.07 and 0.59, respectively) was discovered by Wilcoxon signed-rank test for left and right asymmetry. The developmental stage of upper right and upper left third molars yielded the greatest correlation coefficient. The probability of an individual being over the age of 18 is 95.6% for males and 100.0% for females in case four fully developed third molars are present. Taking into consideration gender, location and number of wisdom teeth, regression formulae were arrived at.

*Conclusion:* Use of population-specific standards is recommended as a means of improving the accuracy of forensic age estimates based on third molars mineralisation. To obtain more exact regression formulae, wider age range studies are recommended.



## 1. Introduction

For purposes of age estimation, teeth can be quite useful. Very accurate age assessment may be gained by observation of dentition status in childhood. Unfortunately, with the completion of the dental development of an individual, this accuracy is also reduced.[1] Environmental, climatic, genetic, hormonal and nutritional factors can affect the development of each person.[2,3] Apparently, external factors affect bone mineralisation more than they do the dental one.[4]

Determination of chronological age within 15–23 years remains problematic despite the existence of a broad range of age estimation methods. Such skeletal indicators as cervical vertebrae, hand–wrist bones, fusion of cranial sutures, epiphysial fusion, changes in the pubic symphysis, amino acid racemisation, or changes in secondary sex characteristics, all have their positive and negative aspects, but in this particular age span are generally indecisive.[5–13]

Our previous study demonstrated that the Demirjian method is an efficient tool for dental age estimation in the 6–13 age range. However, this method is useful as long as the apex of permanent mandibular second molar is open.[14] After that age, the third molars are the only teeth still growing and they are very variable in their pattern of formation: agenesis is frequent, and the age of complete mineralisation varies greatly.[15–19] It was proposed by Garn et al.[20] that third molar agenesis is a relatively common polymorphism

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occurring in 16% of the white population above the age of 14 in Southwestern Ohio. Very variable estimates ranging from 7–10%[21]–32.4%[22] have been produced by more recent studies. For example, a notably high prevalence of third molar agenesis (74% of individuals older than 14 years) in individuals with Down syndrome has been demonstrated by Shapira et al.[23]

Different radiographical scoring methods based on tooth maturation have been suggested.[24] However, in this study, the 10-point scoring classification designed by Gleiser and Hunt[25] and modified by Köhler et al.[26] (MG&H) was adhered to in scoring radiological third molar development. The development of third molars is segmented into 10 stages. Each stage matches to a particular developmental score, ranging from 1 to 10, respectively. This method was selected because of its greater ability, in comparison with the Demirijian method, to discriminate between stages of tooth development.

To investigate the usefulness of the third molar as a dependable age indicator, a number of studies have so far been carried out. These studies demonstrate the necessity for population-specific studies since they indicate that dental development varies slightly between different populations.[16,27–33] Many reports have recently been published on the evaluation of dentition development for different ethnic groups, indicating the need for further studies of Iranian populations.[14,34,35]

Establishment of a radiological database of orthopantomograms from young Iranian adults to obtain regression formulae for age estimation of Iranians, in accordance with the 10 stages of MG&H, was the main goal of the present study. We determined the likelihood of whether an Iranian individual is at least 18 years old from a medicolegal perspective. This age signifies adult status in Iran.

## 2. Materials and methods

### 2.1. Samples

Orthopantomograms of Iranians whose age and sex were known constituted the samples. A convenience sampling method was used. All the radiographs were digitally generated using a Planmeca Promax (Planmeca Oy, Helsinki, Finland), and these radiographs were stored as TIF files. All X-rays were compiled from the Institute of Dentistry and the private practice of one of the co-authors in Mashhad (Razavi Khorasan province, Northeast of Iran), from March 2010 to June 2011. Identity cards provided the information on which the age of the subjects was calculated and converted to a decimal value. Analysis was made of a total of 1274 panoramic radiographs. The subjects were from 15.01 to 22.97 years old. Eight hundred eighty-five females and 389 males of Iranian origin (Table 1) were included in the data set. No medical history, no obvious dental pathology on the orthopantomograms and the presence of at least one third molar constituted additional selection criteria. The study was based on the evaluation of the developmental stage of 4600 third molars (Table 2) and this is shown by the frequency distribution of the number of third molars present on each of the 1274 evaluated orthopantomograms.

**Table 1**
Distribution of studied individuals categorized by gender and age groups.

| Age | Gender | | Total (%) |
|---|---|---|---|
| | Male (%) | Female (%) | |
| 15–15.99 | 22 (1.7) | 49 (3.8) | 71 (5.6) |
| 16–16.99 | 50 (3.9) | 103 (8.1) | 153 (12.0) |
| 17–17.99 | 41 (3.2) | 83 (6.5) | 124 (9.7) |
| 18–18.99 | 40 (3.1) | 114 (8.9) | 154 (12.1) |
| 19.19.99 | 56 (4.4) | 104 (8.2) | 160 (12.6) |
| 20–20.99 | 85 (6.7) | 169 (13.3) | 254 (19.9) |
| 21–21.99 | 58 (4.6) | 143 (11.2) | 201 (15.8) |
| 22–22.99 | 37 (2.9) | 120 (9.4) | 157 (12.3) |
| **Total** | 389 (30.5) | 885 (69.5) | 1274 (100) |

**Table 2**
Distribution of the number of panoramic radiographs for both genders ($n$) indicating respectively 1, 2, 3 and 4 wisdom teeth present, associated with 4600 evaluated third molars on all 1274 orthopantomograms (OPG's).

| $\alpha$ | $n$ | Total |
|---|---|---|
| *Male* | | |
| 1 | 7 | 7 |
| 2 | 25 | 50 |
| 3 | 62 | 186 |
| 4 | 295 | 1180 |
| *Female* | | |
| 1 | 24 | 24 |
| 2 | 81 | 162 |
| 3 | 129 | 387 |
| 4 | 651 | 2604 |
| **Total** | 1274 | 4600 |

$\alpha$: Number of presenting wisdom teeth on each OPG; $n$: number of OPG's; Total: absolute count of wisdom teeth.

### 2.2. Assessment of tooth development scores on orthopantomograms

Each orthopantomograph was coded with a numerical ID so as to prevent observer bias, and the observer, therefore, was not aware of the age or sex of the subjects. Using a 10-stage developmental scoring method (Table 3) proposed by Köhler et al. (MG&H), radiographs meeting these selection criteria were evaluated and, if necessary, imported into Adobe Photoshop CS3 (Adobe Systems Incorporated, San Jose, CA, USA). The radiograph in question was integrated into Adobe Photoshop to enlarge the view, to choose the mesial and distal enamel cement junction of the wisdom tooth in question and the second molar that precedes it, to draw a line from one to the other with the line tool, to come up with a second line from the middle of the root end perpendicular to the first line giving us the details of the length of the roots of both teeth, and to determine their proportions, in case of doubt between two adjacent scoring stages[29] (Fig. 1). To adjust grey scale, brightness and contrast or to convert into a negative image, image quality improvement tools in Adobe Photoshop CS3 were used. The least developed root was examined on pluriradicular wisdom teeth. Corresponding to the stage of root development, all the third molars present on the radiograph were scored. A well-trained observer evaluated all ratings (A.B.). After the passage of 2 months a random sample of 130

**Table 3**
Third molars developmental stages explaining crown and root formation.[26]

| Stage | Score | Explaining |
|---|---|---|
| *Crown formation* | | |
| 1 | 1 | Crown calcification: 1/2 |
| 2 | 2 | Crown calcification: 3/4 |
| 3 | 3 | Complete crown calcification |
| *Root formation* | | |
| 4 | 4 | Initiation of root formation |
| 5 | 5 | Root calcification: 1/4 |
| 6 | 6 | Root calcification: 1/2 |
| 7 | 7 | Root calcification: 3/4 |
| 8 | 8 | Mostly complete root length, root canals terminally spreading away from each other |
| 9 | 9 | Full root length, root canals terminally parallel |
| 10 | 10 | Finished root formation, root canals terminally coming together |

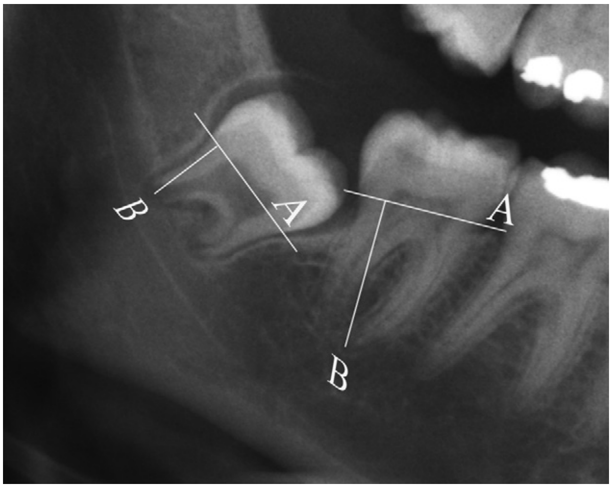


**Fig. 1.** Adobe Photoshop CS3 is applied for precise scoring of mandibular third molar development. Two lines (A and B) are drawn perpendicular to each other. The line A connects mesial and distal cemento-enamel junction; and Line B is drawn from the middle of the root tip perpendicular to the A. Third molar root development is computed from the ratio between root length of third and second molar. In this case, root length is 6.6 and 12.3 for third and second molar root, respectively. Ratio is 0.53. MG&H score is 6 (root calcification is approximately one-half).

(≈10%) radiographs were re-scored as a means of computing intra-observer reliability.

### 2.3. Statistical analysis

Statistical Package for the Social Sciences (SPSS) 16.0 for Windows (SPSS Inc., Chicago, IL, USA), and Microsoft Office Excel 2007 were used to carry out statistical analysis. Intra-observer reliability was evaluated through the use of Kappa statistics. Left–right symmetry in third molar development was evaluated with Wilcoxon signed-rank test because MG&H stages of development were an ordinal variable. We computed the Spearman correlation coefficients between the developmental scores of different third molars. To obtain separate multiple regression formulae for age estimation for males and females, multiple linear regression analysis was performed on the collected database. Several possible combinations of fully developed wisdom teeth were considered to determine the probability that an individual was over 18 years old. The results were considered statistically significant when the $p$-value was less than 0.05.

## 3. Results

The number of individuals included in the sample studied was 1274 and their mean age was 19.49 ± 2.11 years, ranging from 15.01 to 22.97 years (Table 4). By testing intra-observer agreement, method reliability was verified. For intra-observer agreement, the kappa value was 0.873, and 0.835–0.911 was the figure for the 95% confidence interval (CI). Confirming left–right symmetrical third molar development, the Wilcoxon signed-rank test for left and right asymmetry found for each jaw separately no significant difference (z statistic and $p$-value for upper and lower jaws were −1.84, 0.07 and −0.53, 0.59, respectively).

**Table 4**
Descriptive findings of the studied subjects.

| | Males | Females | Total |
|---|---|---|---|
| Number of samples | 389 | 885 | 1274 |
| Minimum age | 15.01 | 15.02 | 15.01 |
| Maximum age | 22.97 | 22.96 | 22.97 |
| Mean age | 19.40 | 19.53 | 19.49 |
| 95% CI | 19.19; 19.60 | 19.39; 19.67 | 19.37; 19.60 |
| S.D. | 2.06 | 2.13 | 2.11 |

CI: Confidence interval; S.D.: Standard deviation.

**Table 5**
Spearman correlation coefficients between upper and lower wisdom teeth in both genders.

| | UR | UL | LR | LL |
|---|---|---|---|---|
| *Male* | | | | |
| UR | 1.00 | 0.96 | 0.82 | 0.81 |
| UL | 0.96 | 1.00 | 0.81 | 0.81 |
| LR | 0.82 | 0.81 | 1.00 | 0.90 |
| LL | 0.81 | 0.81 | 0.90 | 1.00 |
| *Female* | | | | |
| UR | 1.00 | 0.93 | 0.70 | 0.71 |
| UL | 0.93 | 1.00 | 0.68 | 0.71 |
| LR | 0.70 | 0.68 | 1.00 | 0.91 |
| LL | 0.71 | 0.71 | 0.91 | 1.00 |

UR: upper right third molar (TM); UL: upper left TM; LR: lower right TM; LL: lower left TM.

A strong correlation between the different variables (Table 5) was demonstrated by significant Spearman correlation coefficients. The developmental stage of upper right (UR) and upper left (UL) third molars yielded the greatest correlation coefficient, namely 0.96 and 0.93 for males and females, respectively. Correlation coefficients of a similar nature were found between lower right (LR) and lower left (LL) third molars (0.90 for males and 0.91 for females).

Formulae for females and males both were produced by the linear multiple regression analysis with backward elimination,[36] the dependent variable being the chronological age and the independent variables being the third molars root development stage. In this method, we first include all variables in the regression model and then remove consecutively the variables that do not predict the model so that the last model includes only useful variables. In case an individual had four third molars present, the model of age estimation in males could only be predicted by UR and LL developmental stage, while in the case of a female adult in the same condition UL developmental stage did not have any effect in age estimation (Table 6). For males, $R^2$ varied from 0.40 to 0.68 and for females from 0.24 to 0.61, depending, of course, on the number of wisdom teeth available in an individual. This coefficient is a statistical measure of how well the regression line estimates the real data points. In our study, the coefficients of determination ($R^2$) are somewhat low. Therefore, we can conclude that these regression formulae cannot predict subject age, precisely (Fig. 2). The 95% CI of the difference between the estimated chronological age and the true one was about −0.16; 0.16 years and −0.21; 0.03 years in males and females, respectively, where all four third molars were present. The above findings showed that there was no statistical difference between true and estimated chronological age where four third molars were present. In both genders, the difference between estimated dental age and chronological age (EDA-CA) was higher in younger subjects. The most accurate age for application of these regression formulae was for adults in the age range of 19–21 years (Fig. 2).

The probability of an individual being over the age of 18 is expressed in Table 7, taking into consideration the location and number of fully developed wisdom teeth. The probability is 95.6% and 100.0% for males and females, respectively, where four fully developed third molars are present.

## 4. Discussion

Many studies have documented different maturation stages of wisdom teeth. In these studies, we encounter differences

**Table 6**
Multiple linear regression formulae (backward elimination) for age assessment of Iranian young adults.

| MG&H method | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| TM present | Male | | | | Female | | | |
| | Formula | $R^2$ | S.D. | 95% CI of EDA-CA | Formula | $R^2$ | S.D. | 95% CI of EDA-CA |
| UR/UL/LR/LL | 12.09 + (0.24 × UR) + (0.60 × LL) | 0.54 | 1.40 | (−0.16, 0.16) | 12.81 + (0.16 × UR) + (0.24 × LL) + (0.40 × LR) | 0.46 | 1.56 | (−0.21, 0.03) |
| UR/UL | 12.70 + (0.67 × UL) | 0.40 | 0.99 | (−0.72, 0.62) | 16.72 + (0.38 × UL) | 0.24 | 1.24 | (−0.40, 0.42) |
| LR/LL | 10.94 + (1.01 × LL) | 0.68 | 1.35 | (−0.92, 0.99) | 12.97 + (0.88 × LR) | 0.61 | 1.49 | (−0.53, 0.54) |

TM present: third molar present; UR: developmental stage of upper right third molar; UL: developmental stage of upper left third molar; LR: developmental stage of lower right third molar; LL: developmental stage of lower left third molar; $R^2$: coefficient of determination; S.D.: standard deviation; CI: confidence interval; EDA: estimated dental age; CA: chronological age.

concerning the number of stages, the manner in which each stage is defined and presented and the part of third molar development chosen to be analysed. For Iranian courts, the age that has the greatest judicial significance is the age of 18. It is quite likely that about this age, the third molar has a fully developed crown and that root formation is taking place. During this large age span of root development, the seven distinct root scores of MG&H provide a reliable and useful value. To define fewer scores is the same as leaving more time (age) between the different formation rates and this means failure to attain our forensic purpose, which is to make age estimation as precise as possible.[27] Also, the numerical nature of this method makes it easy to be used in regression formulae and automation objectives. We should keep in mind, however, that reliance on dental methods as a base for age estimation has its shortcomings, especially during adolescence when the only variable dental indicator left, is the third molar. Undoubtedly, there is much variation in position, morphology and time of formation. Other noteworthy deficiencies in this method include differences between populations, use of different methodologies and dissimilarity between observers.[16]

To overcome some of the above-mentioned deficiencies, in this study, all subjects selected were Iranians. To evaluate the developmental sequence of wisdom teeth from the age of 15 to that of 22, panoramic radiographs of Iranian youngsters were used.

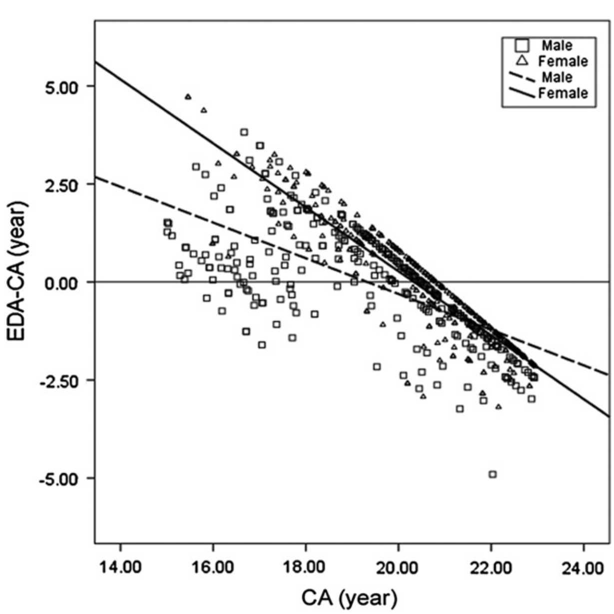


**Fig. 2.** Scatterplot and regression lines of the difference between estimated dental age and chronological age (EDA-CA) against the chronological age (CA) for both genders where four third molars were present.

To provide a more uniform scoring system when there is doubt classifying a radiograph's exact development score, radiographs are integrated into Adobe Photoshop CS3 and the prescribed protocol is applied. It is true that this system cannot be applied before score 4 (beginning of root formation); however, this is not important when estimating the age of the majority. In fact, stages 1, 2 and 3 fell outside the age range of this study.

The value we attained for intra-observer agreement was high and similar to those obtained by others.[34,37] Compared to our study, however, those that used the Demirjian method, had a higher kappa value.[38–40] In those studies, better kappa statistics and higher percentage of identical readings were attained by methods that had fewer stages.[37]

For males, the left–right symmetry in third molar development expressed by the Spearman correlation coefficient was discovered to be higher in the maxilla than in the mandible. This maximum Spearman correlation coefficient was found between UR and UL (Table 5) in male and female individuals. Though they considered males and females as a whole and applied the Demirjian method, the findings of the Rai et al. study on an Iranian population aged 10–27 demonstrated that Spearman correlation coefficient of UL and LL was the highest (0.94).[34] In a study on Caucasian Belgian patients, Gunst et al.[16] demonstrated that the Spearman correlation coefficient of UR and UL was 0.97 and 0.98 for males and females, respectively, and of LR and LL it was 0.93 and 0.95 for males and females, respectively. The larger sample size (2513 vs. 1274) and ethnic differences may account for somewhat higher Spearman correlation coefficients found in Gunst et al.'s study.

All possible age estimation methods suitable for a particular case should be attempted to achieve best age determination.[41] In the final report, each obtained outcome should be evaluated in function of its mutual weight and proportionally taken into account. Thus, if possible, we should calculate all regression formulae in this study and report the mean as probable dental age. The formula that involves the lower wisdom teeth alone should be used in cases where the upper third molars are, due to frequently appearing radiological overlap with maxillary tuberosity or the bottom of the maxillary sinus, more difficult to score.[29] In this

**Table 7**
The probability of an Iranian young adult with fully developed third molars being older than 18 years.

| Chance > 18 years (%) | Male | Female |
|---|---|---|
| UR = 10[a] | 93.1 | 91.2 |
| UL = 10 | 92.8 | 90.9 |
| LR = 10 | 95.5 | 97.1 |
| LL = 10 | 96.7 | 96.6 |
| UR + UL = 10 | 93.3 | 91.8 |
| LR + LL = 10 | 95.9 | 100.0 |
| UR + UL + LR + LL = 10 | 95.6 | 100.0 |

UR: upper right third molar (TM); UL: upper left TM, LR: lower right TM; LL: lower left TM.
[a] MG&H score = 10.

research, regression formulae considering the multicollinearity problem were obtained. When multiple wisdom teeth are present, the problem of multicollinearity, especially between upper left and right or lower left and right third molars, is often encountered. Therefore, the third molar, which statistically contributed least to that particular regression model, was omitted. Through the use of variance inflation factor (VIF), multicollinearity diagnostics was best attained. Variables in which VIFs were greater than 10 were not considered.[36]

Several possible combinations of fully developed wisdom teeth (as seen in Table 7) were measured to determine the probability that an individual had reached the age of 18 and was therefore considered an adult. These percentages demonstrate how certain we can be as to whether an individual has reached the age of 18 years or not. Meinl et al.[42] reached the conclusion that the probability that an Austrian is at least 18 years old is 99.5 for males and 99.3% for females, where two mandibular molars are present and tooth mineralisation is completed (Demirjian's stage H). Similarly, Caldas et al. carried out a study of a Portuguese population and discovered that stage H of LR is a good predicting factor for evaluating an individual to be over the age of 18.[43] The different scoring methods used produce these higher values. Stages 9 and 10 of the MG&H method may be regarded as Demirjian's stage. H. Gunst et al. demonstrated that this chance is 96.3% for males and 95.1% for females when four fully developed wisdom teeth are present.[16] This probability was 95.6% for males and 100% for females in our study. Put another way, the probability of age being below 18 years was 4.4% in males with four fully developed third molars. In the same situation, this chance for a young adult female should be considered as zero.

## 5. Conclusion

We can conclude from this study that in the presence of all four third molars:

1. On the basis of regression formulae with a standard deviation of 1.40 years for males or 1.56 years for females, we can estimate the chronological age of an Iranian.
2. In cases where four third molar teeth development is completed (MG&H score = 10), the probability of an Iranian being older than 18 years is 95.6% for males and 100% for females.

We suggest that population-specific standards be employed as a means of increasing the accuracy of forensic age estimates based on third molars mineralisation. We also propose that to obtain more precise regression formulae, wider age range studies should be carried out.

*Conflict of interest*

None declared.

*Funding*

None declared.

*Ethical approval*

The responsible ethics committee of Mashhad University of Medical Sciences approved this study.

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